New Research Topics

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Fixturing/Workholding

- Fixture-Workpiece Dynamic Stability Analysis

- Adaptive Chucking for Ring Shaped Parts

Micro-Cutting Processes

- Micro-Cutting Process Modeling

- Laser Assisted Micromechanical Machining

Dynamic Modeling and Stability Analysis of Fixturing

(Sponsor: NSF)

- **Objective:** Develop a model to predict the dynamic behavior and stability of the workpiece.
- **Approach:** The workpiece's rigid body motions due to clamping and machining are modeled. The status of each individual contact is monitored during machining to detect any undesired situations.
- **Broader Impact:** The result of this study will lead to improved understanding of the impact of design parameters of a fixture on machining process.
- **Significant Results:** The following question is answered: given clamping preloads and machining loads, will the workpiece be stable or not during machining?

Solve the dynamic model for workpiece rigid body motion

↓

Map the workpiece motion into the contact displacements

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Compute the static contact displacements

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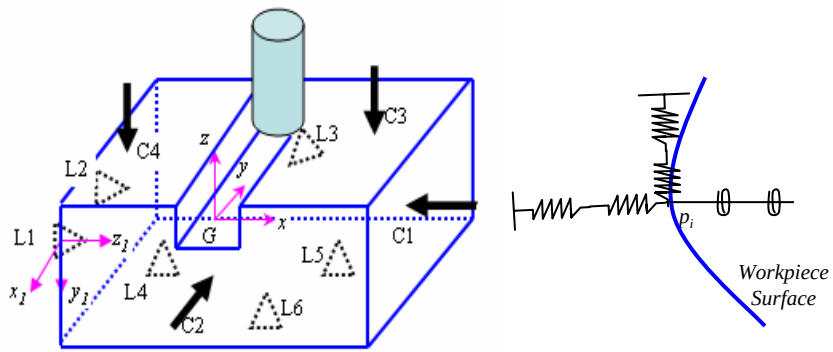
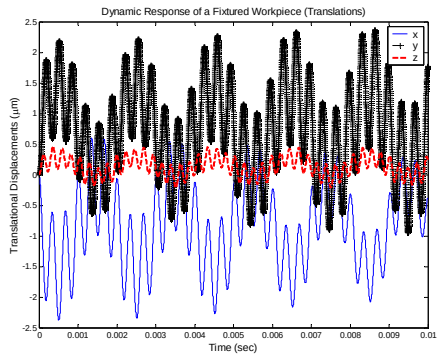
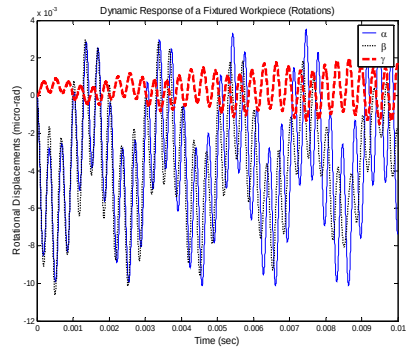
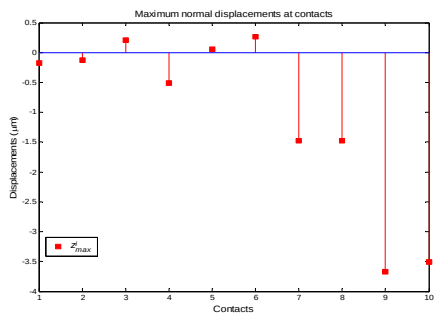
Superpose the dynamic and static contact displacements and detect any lift-off and/or gross slip at contacts

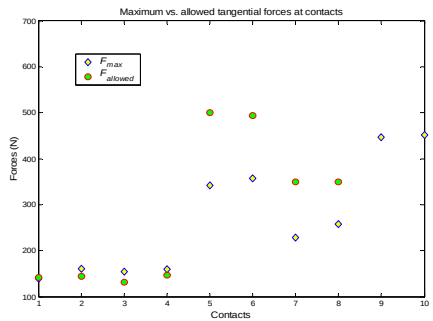
Procedure for Stability Verification



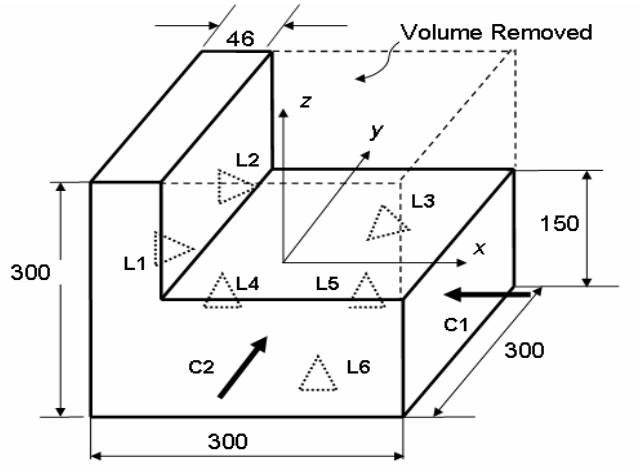




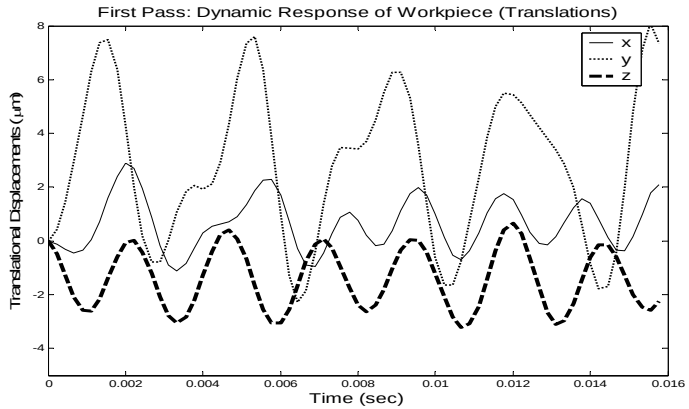




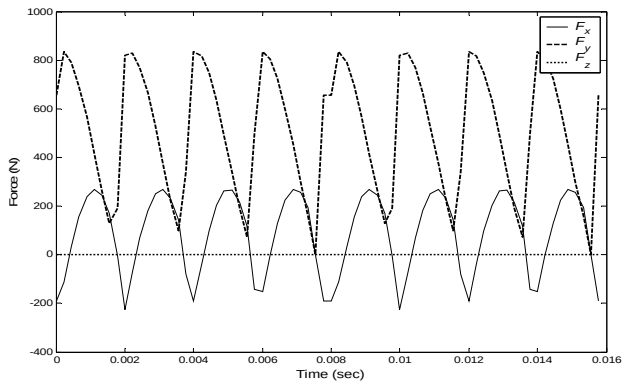
Effect of Material Removal on Stability



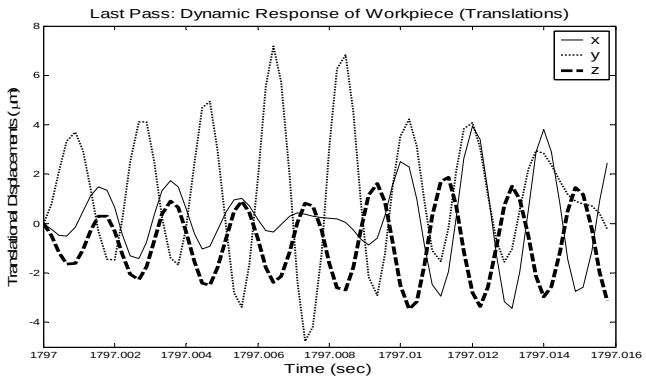
Example part and fixture layout



Rigid body translations of workpiece during the **first** pass of machining

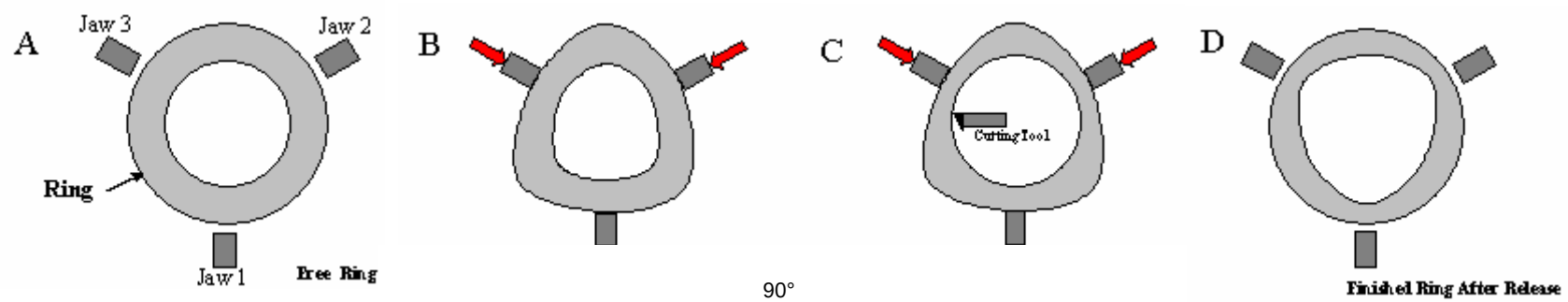


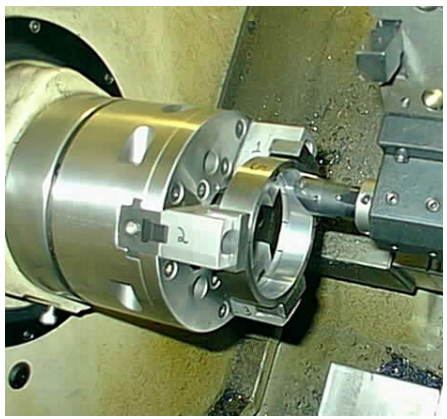
Machining Forces

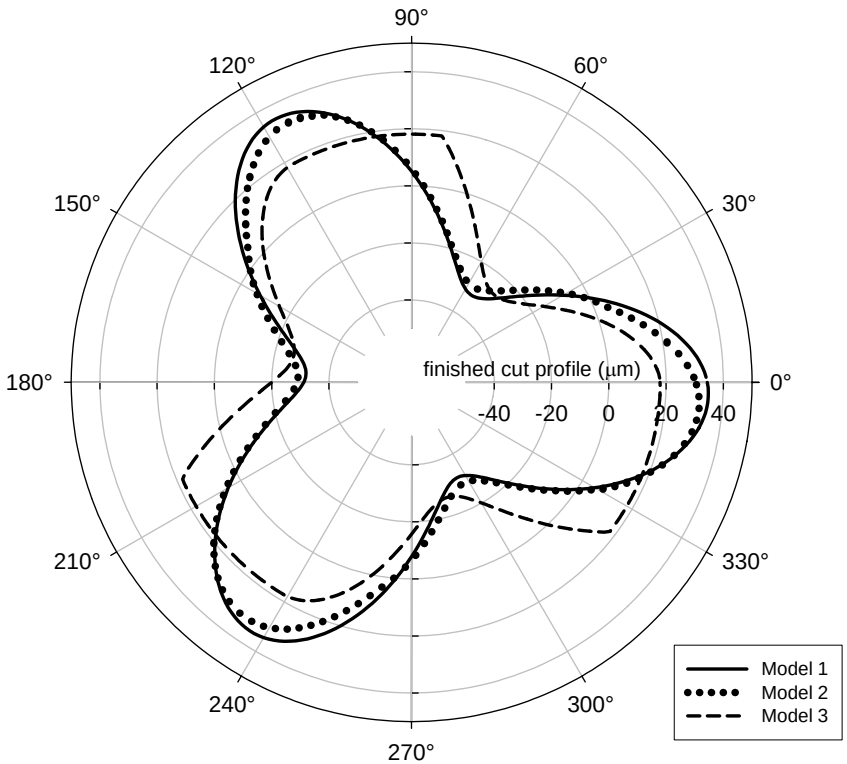


Rigid body translations of workpiece during the **last** pass of machining

Adaptive Chucking for Ring Shaped Parts





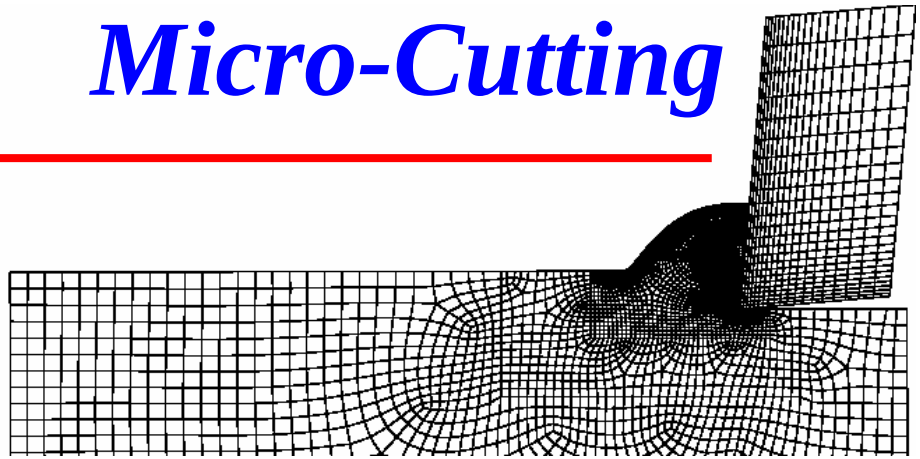


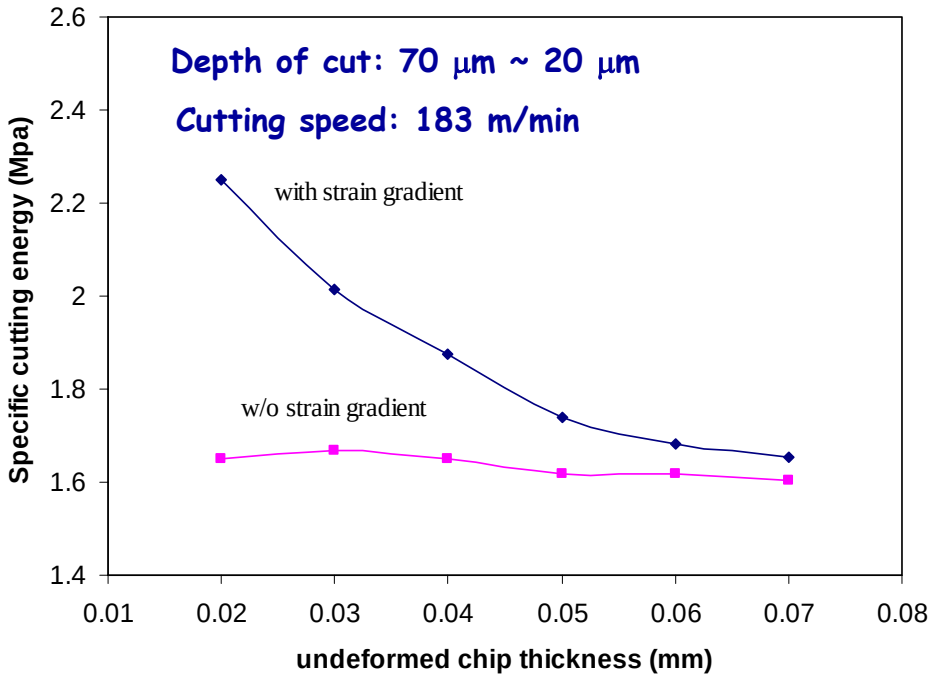
Proposed Solution:

Design and build a chuck with independently and adaptively controlled jaw forces

(S.N. Melkote)

Size-Effect In Micro-Cutting

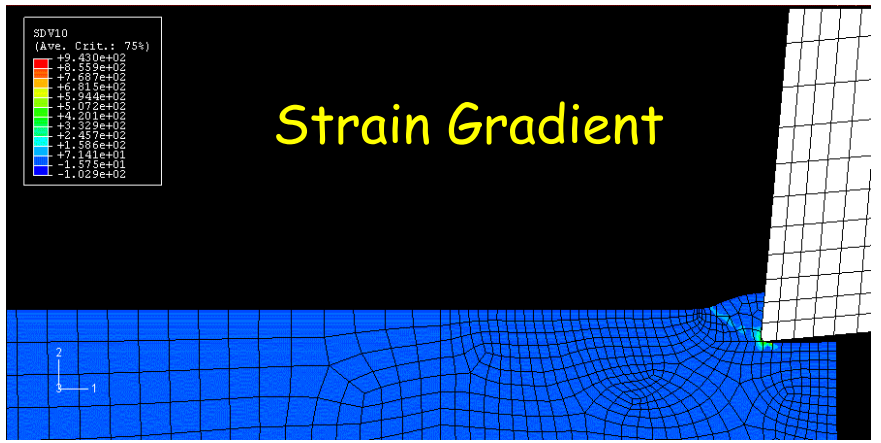


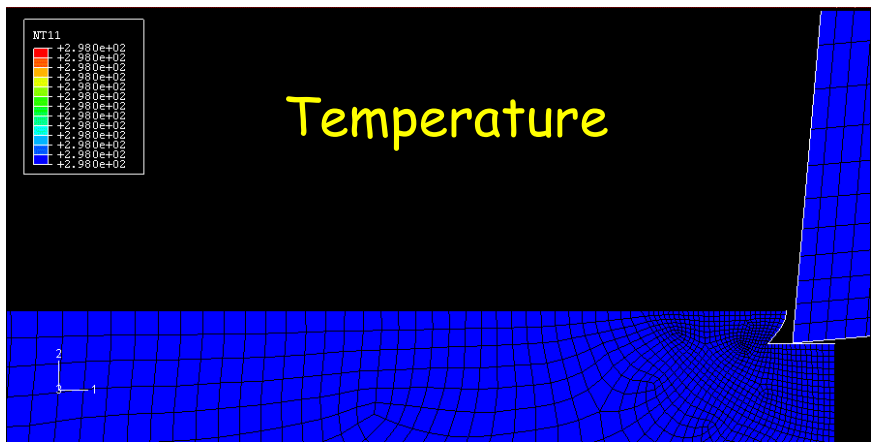


Predicted Variation of specific cutting energy

Tool and workpiece properties

Density (kg/m^3)	7827
Specific Heat (J/kg ^oC)	458
Thermal Conductivity (W/m-K	46.6
Young's Modulus (GPa)	210
Poisson's ratio	0.277
Flow stress constants	$s = A + Be^n$
A (MPa)	688.17
B (MPa)	150.82
n	0.3362
Coefficient of friction at tool-chip interface	0.3





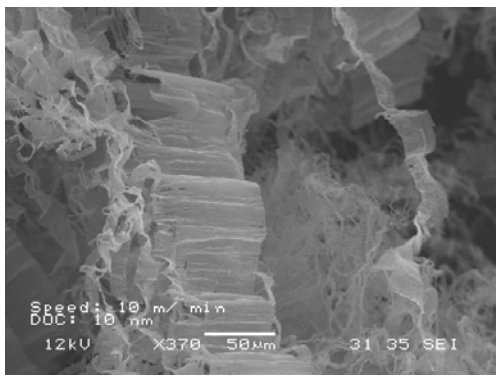
Micro/Nano Machining Experiments

- Single crystal diamond tool for non-ferrous material
  - Edge radius ~ 65 nm
  - Rake angle: 0°
  - Clearance angle: 5°

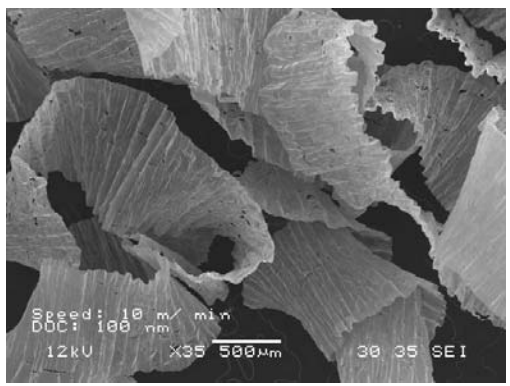
Machine:

- Toshiba Machine ULG-100 (H^3)
  - Micro/Nano machining experiments

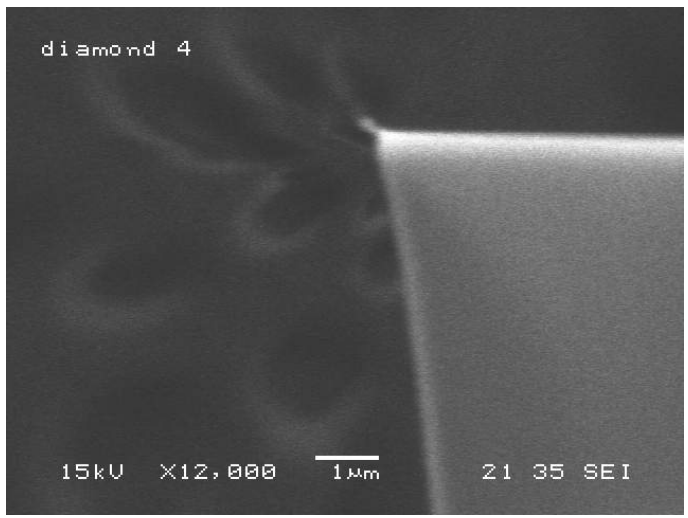
Cutting Speed: 10m/ min



DOC: 10 nm



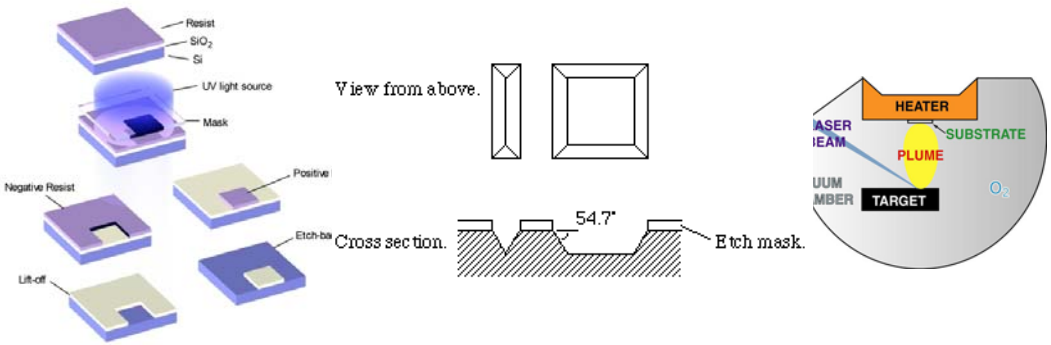
DOC: 100 nm



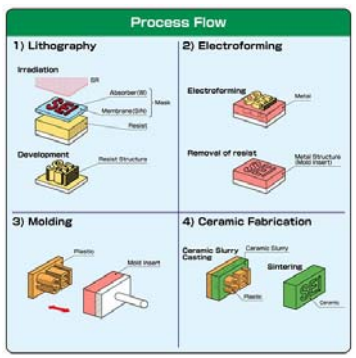
Conventional vs. Mechanical Micromachining

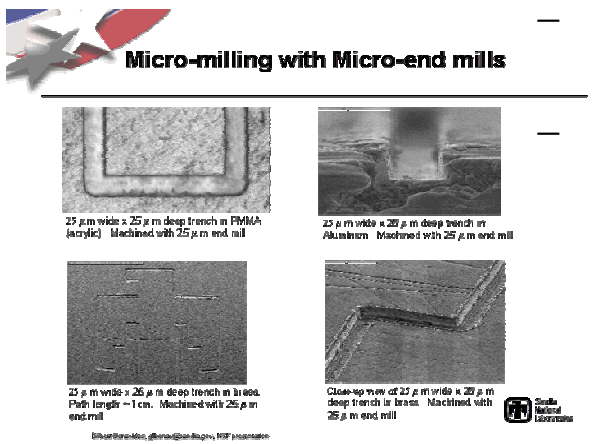
Conventional Microstructuring

- Silicon-based & low aspect ratio features
  - Optical/X-ray Lithography [1]
  - Etching
  - Laser Ablation [2]



- Versatile (metal and polymers) and high aspect ratio features by LIGA [3]

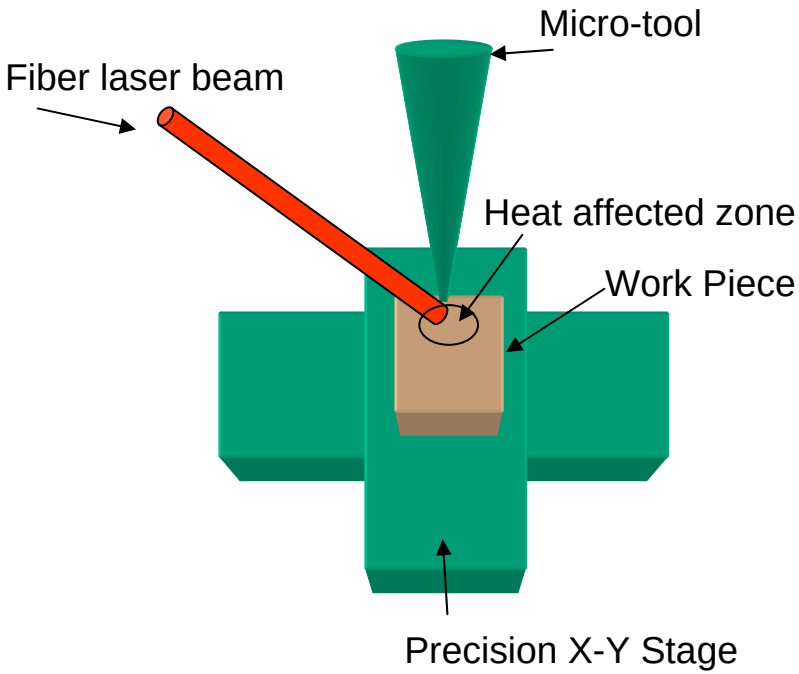




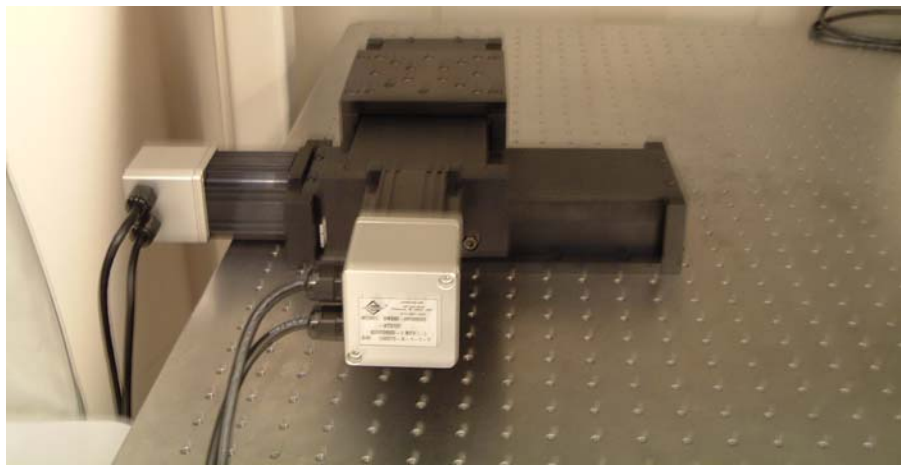
Mechanical Micromachining

- Advantages over conventional methods
  - Variety of materials can be processed
  - High aspect ratios can be achieved
  - No need for clean room
  - No synchrotron radiation machine required for X-ray
  - No sacrificial layer
  - Complex 3-D surfaces can be realized
  - Economical

Laser Assisted Mechanical Micromachining (LAMM)



IPG 2-10W 1064 nm Fiber Laser



High Precision Positioning Stage

Laser Assisted Mechanical Micromachining (LAMM) – Research Issues

- Process characterization
  - Cutting forces, surface finish, tool wear, sub-surface damage
- Modeling
  - Thermal modeling of heat affected zone
  - Cutting force prediction
- Process optimization
  - Tool wear
  - Surface quality and subsurface damage